THE ALIMENTARY CANAL OF SPHAERODERUS NITIDICOLLIS CHEV. VAR. SCHAUMI CHD. (COLEOPTERA)*

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During the summer of 1930, while collecting insects at the Franz Theodore Stone Laboratory, Put-in-Bay, Ohio, one of the carabidæ was found feeding on snails. The species was identified by Mr. L. L. Buchanan of the U. S. National Museum as *Sphaeroderus nitidicollis Chevrolat variety schaumi Chaudoir.* The species was found in a restricted locality on but one of the islands in that vicinity. The beetle is about two centimeters long, has a narrow head and prothorax, large mandibles and is of a violaceous color. Since the writer is very much interested in Carabidæ in general, at the advice and direction of Dr. C. H. Kennedy a study of the internal morphology of this species was undertaken.

The species ranges from Hudson Bay to northern Virginia but is rarely taken. Comparatively few specimens were found even after intensive search. These were fixed in Kahle's fluid and preserved in seventy per cent alcohol. The study was carried on through the fall and winter, but the scarcity of material made it somewhat restricted. It is hoped that more material may be obtained in order to complete a more intensive study of the morphology and physiology.

The author wishes to express deep appreciation for the suggestions, criticisms and assistance so freely given by Dr. Kennedy and for the helpful comments of many of his fellow-students.

Gross Anatomy of the Digestive Tract.

There are three main divisions of the alimentary canal determined by the embryonic origin. The anterior portion (stomodaeum or fore-gut) arises as an invagination at the cephalic end of the embryo. The posterior portion appears similarly at the caudal end. These two parts, therefore, are ectodermal in origin. The mesenteron or mid-gut is formed by the proliferation of cells in the endodermal tissue and eventually connects the fore-gut to the hind-gut forming a continuous tube.

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The three regions are further differentiated to forms:

1. Fore-gut.
   a. Mouth or buccal cavity.
   b. Pharynx.
   c. Oesophagus.
   d. Gizzard (proventiculus).
   e. Oesophageal valve.
2. Mid-gut (venticulus).
   a. Anterior mid-gut.
   b. Posterior mid-gut.
3. Hind-gut.
   a. Pyloric valve.
   b. Malpighian tubules.
   c. Ileum.
   d. Rectum.
   e. Anal opening.

Though some variation occurs the different parts will usually be found to lie as follows: The fore-gut passes caudad along the median axis to the first abdominal segment where it joins the mid-intestine. The mid-intestine continues caudad for about a quarter of its length bending to the right in the second abdominal segment then sharply to the left. The posterior quarter of the mid-gut curves dorsad, at right angles to the antero-posterior axis, and joins the ileum at about the fourth abdominal segment. The ileum curves left and ventrad sometimes forming a sharp half loop, to the sixth abdominal segment joining the rectum, which is more or less covered by the chitinous sheath surrounding the genitalia. The rectum is bellows-like and capable of considerable elongation.

The Fore-Intestine.

The alimentary tract of the adult is about three cm. long, approximately one and a half times the length of the body, of this, the fore-gut comprises a little more than one fourth. The *pharynx* appears as a short dilated portion just posterior to the mouth. The *oesophagus* normally is smaller than the pharynx but is capable of some dilation. The *gizzard* or proventriculus may be distinguished as an enlarged rounded portion just anterior to the junction of the fore-gut and the mid-gut. The *oesophageal valve* is not apparent externally.

The Mid-Intestine.

The mid-intestine forms somewhat more than a third of the entire tract and is divided into two distinct portions approximately equal in length. The anterior portion is about twice the diameter of the posterior part but both are densely covered with papillæ those on the posterior portion being smaller, gradually diminishing in size towards the distal end.

The Hind-Intestine.

The beginning of the hind-gut is marked by the *malpighian tubules* of which there are four each having a separate entry, though the two dorsal tubes are somewhat nearer each other than the dorso-ventral

tubes on either side. (See Fig. 12, Plate III). The tubes are long and greatly coiled, so much so that they could not be measured in the preserved material, no fresh material being available. The *pyloric valve* is immediately anterior to the tubules but is not distinguishable externally. The hind-gut makes up approximately one-third of the digestive tract. The *ileum* is but little more than half the diameter of the posterior mid-gut though it comprises a little less than two-thirds of the hind-intestine. There appears to be a constriction at the junction of the ileum and rectum but no valve was demonstrated. The *rectum* is somewhat cone-shaped the anterior portion being the larger, in this region the ovoid rectal pads, six in number, show plainly through the transparent wall. Due to the bellows-like form of the rectum it may be elongated considerably.

On either side of the rectum appears a comparatively large ovoid sac the ducts of which open one on either side of the anus. These are probably the anal glands from which a rather acrid fluid is emitted if the insect is disturbed.

Histological Structure of the Alimentary Canal.

Histological Structure of the Fore-Intestine.

The fore-intestine being formed by the invagination of the body wall has approximately the same structure. Microscopical study of cross-sections from this region demonstrates the following differentiated areas: (1) a chitinous inner lining, intima, (2) an epithelium of hypodermal cells, (3) longitudinal muscles, (4) circular muscles, (5) and an enveloping membrane of connective tissue, "Peritoneum." (This term is improperly applied to insect tissue.)

The general structure of the fore-gut is the same throughout though some differences in detail may be noted.

The chitinous intima is plainly visible from the mouth to the junction of the fore-intestine and the ventriculus. In the anterior portion of the tube it is smooth and comparatively thin, but posteriorly it becomes thickened and densely covered with cilia-like structures, within the gizzard chitinous pads are found between the teeth. (See Fig. 5, Plate II.)

The epithelial layer of hypodermal cells is not so apparent in the oesophagus, individual cells being somewhat flattened. In the gizzard, however, they are either cuboidal or columnar in form and may be readily distinguished. (See Fig. 5, Plate II).

The longitudinal muscles of this region are gathered into four groups which lies in folds of the epithelium. Cephalad these groups are small, becoming larger in the pro-ventriculus, (See Figs. 2 and 4, Plate I, Fig. 5, Plate II).

The circular muscles appear outside the longitudinal muscles in scattered strands near the head but increasing to several layers around the pro-ventriculus (gizzard). (See Figs. 2 and 4, Plate I, Fig. 5, Plate II).

Traces of a "peritoneal membrane" composed of connective tissue may be found here and there, though it is largely obscured by the fatty tissue surrounding the fore-gut.

The oesophageal valve is located at the junction of the fore- and mid-intestine. This consists of a fold of the fore-gut which extends but slightly into the lumen of the mid-gut. At this point the numerous circular muscles largely fill the constriction between the gizzard and the ventriculus. In this region there is a complete reversal in the position of the muscles, the longitudinal muscles of the mid-gut lying outside the circular muscles. (See Fig. 3, Plate I).

Histological Structure of the Mid-Intestine.

The mid-intestine which is bounded anteriorly by the oesophageal valve, posteriorly by the pyloric valve, is divided into two distinct regions approximately equal in length, the anterior portion being nearly twice the diameter of the posterior part. This region is entirely covered by papillæ, those of the fore part being much larger than the ones on the hinder portion.

A histological study of the mid-gut shows the two parts to be much the same save for size. Four rather definite layers are distinguishable: (1) epithelium of endodermal tissue, (2) circular muscles, (3) longitudinal muscles and (4) connective tissue termed the "peritoneal membrane."

The epithelial layer may vary in form and appearance depending on whether it is in the resting phase or the secretory phase. Shortly after taking food the cells are distended some of them breaking off to supply digestive fluids (holocrine secretion). These cells burst and pass off, new cells being formed by certain regenerative tissues contained in the crypts. (See Fig. 8, Plate II). There is some evidence for a merocrine secretion as well, for large globules of liquid may be noted exuding from the crypts during certain phases of the digestive process. (See Fig. 8, Plate II).

The papillæ which cover the surface of the mid-intestine, commonly termed crypts, contain at the tip a mass of generative tissue called a nidus. These nidi probably form the secretory cells of the epithelial layer. The nidi have sunken into the wall of the ventriculus, eventually breaking through to form the crypts which appear on the outer surface of the mid-gut. These are not what are ordinarily termed gastric coecae.

Just outside the basement membrane the circular muscle may be seen; ordinarily two or three layers appear.

The longitudinal muscles (which are reversed in position relative to those of the fore- and hind-gut) appear only in scattered groups and are not numerous.

A very thin "peritoneum" surrounds the entire mid-intestine. (See Figs. 6 and 7, Plate II).

(Although a differentiation occurs in the two regions of the mid-gut no valve was found between them and no division in function is discernible unless the fore part which has the larger crypts is primarily digestive and the hinder portion absorptive. However, much the same type of epithelial cells appear in both regions. (See Figs. 6 and 7, Plate II).

Histological Structure of the Hind-Intestine.

Externally the division between the hind-intestine and the ventriculus is marked by the malpighian tubules. Those are made up of large irregular cells with rather large ovoid nuclei. (See Fig. 21, Plate III). The cells may vary in number from five to twelve in cross section. The inner surface of the tubules appears to be striated, though this does not appear for a short space from the opening into the lumen of the gut. The outer surface is covered by a very thin membrane.

A histological examination of the hind-gut reveals, (1) an intima, (2) an epithelial layer of hypodermal cells, (3) a layer of circular muscle, (4) an outer layer of longitudinal muscle and (5) a "peritoneum" of connective tissue.

Internally the division between the ventriculus and the hind-intestine is marked by the pyloric valve. This consists of a definite fold in the epithelial layer of the ileum. (See Fig. 9, Plate III).

The intima in the region of the pyloric valve is so thin that it is not apparent though it may be plainly seen in the rectum.

The inner layer of longitudinal muscle which ordinarily should be found in the hind-gut does not appear.

The circular muscles which function in closing the valve are very numerous. (See Fig. 9, Plate III).

Just outside the layer of circular muscle may be found a few strands of outer longitudinal muscle. (See Fig. 9, Plate III).

A very thin "peritoneum" is found surrounding the pyloric region.

The intima of the ileum is so thin it appears merely as a line, but the epithelial layer is very thick. The epithelial cells in the ileum are columnar and form folds which almost completely fill the lumen of the tube. Two or three layers of circular muscles are visible but the longitudinal muscles are evident only as a few scattered groups.

The rectum is much greater in diameter than the ileum, though the walls are very thin, so thin that in the anterior portion the six large ovoid rectal pads lying on the inner surface may be plainly distinguished. The intima of the rectum is thicker than in any other part of the hind-gut.

The rectal pads are composed of large columnar cells which form pads between the intima and the basement membrane. (See Fig. 14, Plate III). Outside the pads the thin epithelial layer is visible.

The circular muscles are but scattered strands and the longitudinal muscles may be seen only in one or two isolated groups.

The connective tissue or "peritoneum" appears only here and there. (See Fig. 14, Plate III).

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EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Dorsal view showing gross dissection of the Alimentary Canal. OES.—oesophagus; GIZ.—gizzard (proventriculus); A.M-GUT—anterior mid-gut; P. M-GUT—posterior mid-gut; M. TUB.—malpighian tubule; IL.—ileum; REC. PAD—rectal pad; AN. GL.—anal gland.

Fig. 2. Cross-section through the Oesophagus. EPI.—hypodermal epithelium; LU.—lumen of fore-intestine; IN.—intima; C. MUS.—circular muscle; L.MUS.—longitudinal muscle; MUS.?—probably muscle. (This section is magnified approximately one and a half times more than the section of the oesophagus caudad to this in Fig. 4.)

Fig. 3. Longitudinal section showing the Oesophageal Valve. EPIT.—endodermal epithelium; OES. VL.—oesophageal valve; LU.—lumen of fore-intestine; EPI.—hypodermal epithelium; IN.—intima; OES.—oesophagus; CE.—crypt on mid-gut; C. MUS.—circular muscle; C. TIS.—connective tissue, "Peritoneum;" L. MUS.—longitudinal muscle.

Fig. 4. Cross-section through the Oesophagus posterior to Fig. 2. C. MUS.—circular muscle; C. TIS.—connective tissue, "peritoneum;" L. MUS.—longitudinal muscle; LU.—lumen of fore-gut; IN.—intima; EPI.—hypodermal epithelium.

PLATE II.

Fig. 5. Cross-section through the Gizzard (proventriculus). C. TIS.—connective tissue, "peritoneum;" C. MUS.—circular muscle; L. MUS.—longitudinal muscle; EPI.—hypodermal epithelium; IN.—intima; LU.—lumen of fore-gut.

Fig. 6. Cross-section through the anterior Mid-Gut. LU.—lumen of mid-gut; EPIT.—endodermal epithelium; C. MUS.—circular muscle; L. MUS.—longitudinal muscle; CR.—crypt.

Fig. 7. Cross-section through the posterior Mid-Gut. LU.—lumen of mid-gut; EPIT.—endodermal epithelium; C. MUS.—circular muscle; L. MUS.—longitudinal muscle; CR.—crypt.

Fig. 8. Longitudinal section through a Crypt of the anterior mid-gut. HOL.—holocrine secretion; EPIT.—endodermal epithelium; C. MUS.—circular muscle; L. MUS.—longitudinal muscle; C. TIS.—connective tissue, "peritoneum;" SEC.—globule of secretion (merocrine).

PLATE III.

Fig. 9. Longitudinal-section through the Pyloric Valve. EPIT.—endodermal epithelium; C. MUS.—circular muscle; L. MUS.—longitudinal muscle; PY. VL.—pyloric valve; C. TIS.—connective tissue, "peritoneum;" LU.—lumen of hind-intestine.

Fig. 10. Detail drawing of Fig. 12. M. TUB.—malpighian tubule; C. TIS.—connective tissue, "peritoneum;" L. MUS.—longitudinal muscle; CR.—crypt; C. MUS.—circular muscle; EPI.—hypodermal epithelium (?); ?—probably epithelial tissue; LU.—lumen of hind-gut.

Fig. 11. Cross-section through a Malpighian Tubule. S. B.—striated border; LU.—lumen of tubule; C. TIS.—connective tissue, "peritoneum."

Fig. 12. Diagrammatic drawing made from series of sections to show entry of each of the four Malpighian Tubes.

Fig. 13. Cross-section through the Ileum. L. MUS.—longitudinal muscle; C. MUS.—circular muscle; LU.—lumen of hind-gut; EPI.—hypodermal epithelium; C. TIS.—connective tissue, "peritoneum."

Fig. 14. Cross-section through the Rectum showing the Rectal Pads. REC. PAD—rectal pad or gland; IN.—intima; EPI.—hypodermal epithelial tissue; L. MUS.—longitudinal muscle; C. MUS.—circular muscle; LU.—lumen of hind-gut.

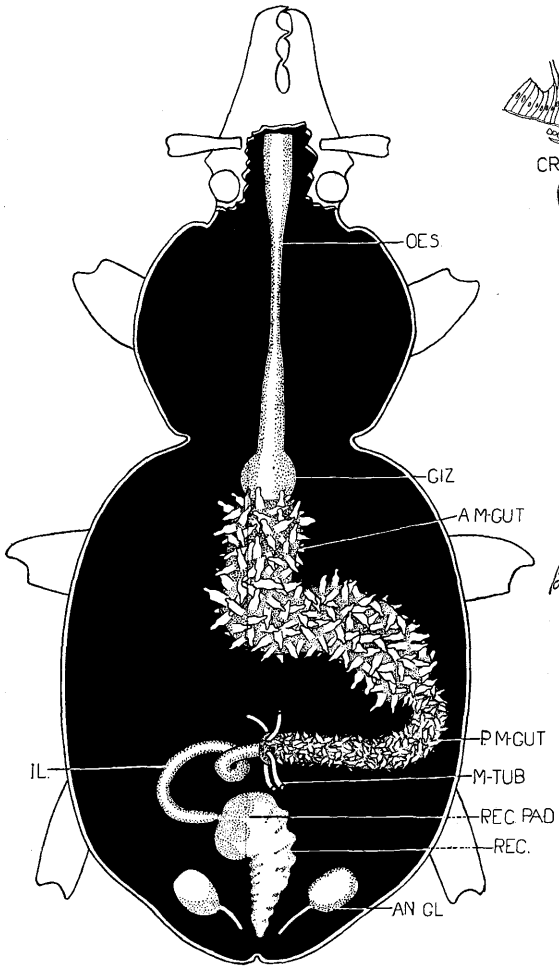
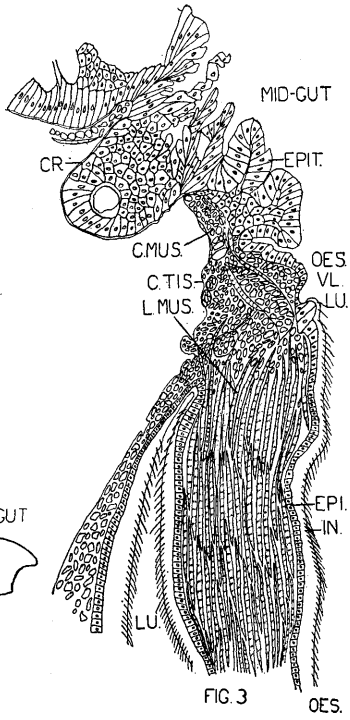


FIG. 1



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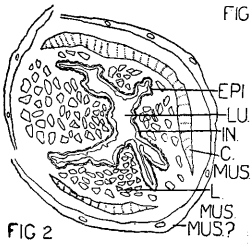

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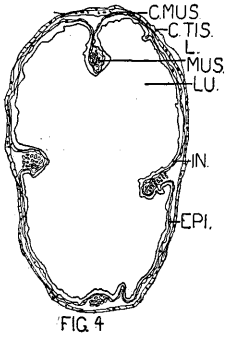

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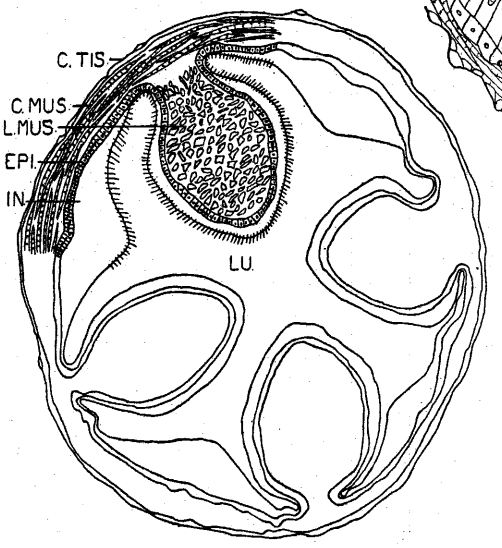

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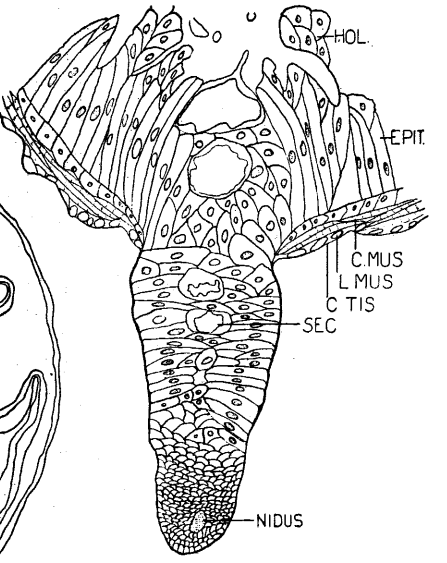

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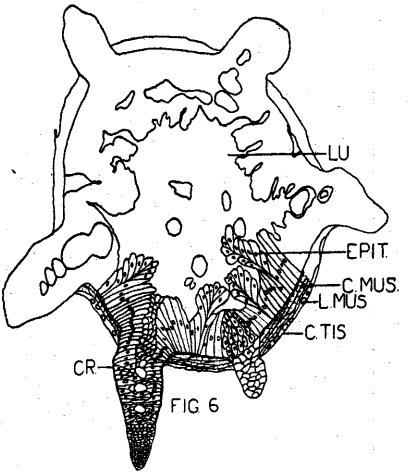

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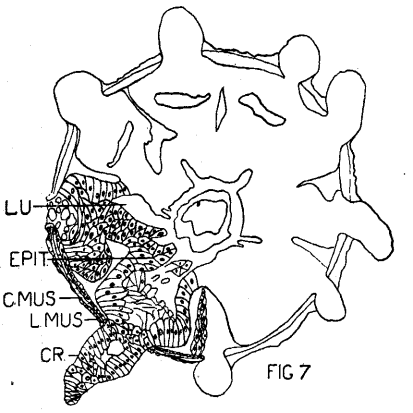

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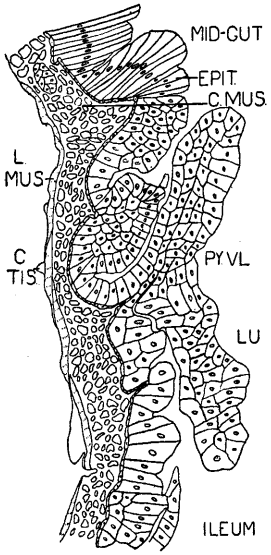

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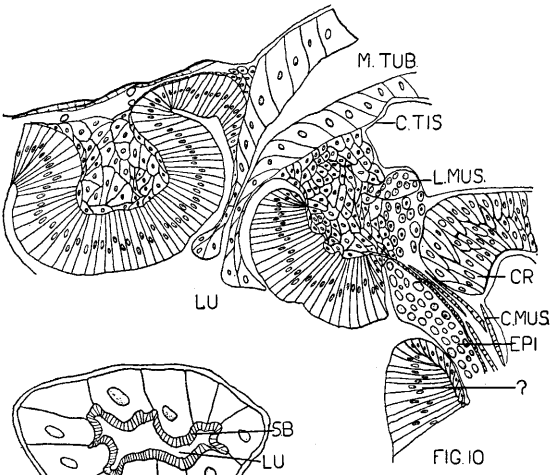

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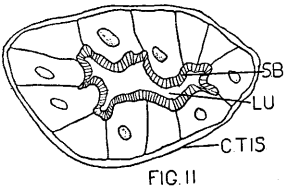

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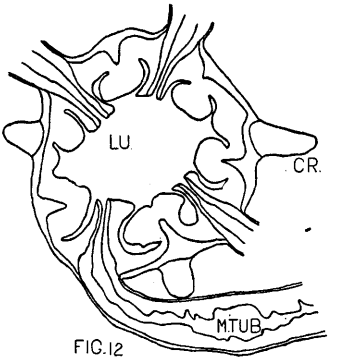

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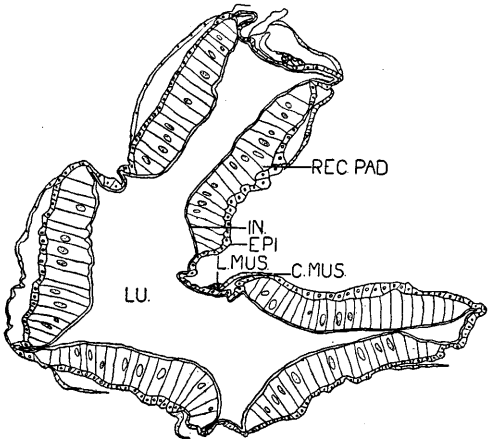

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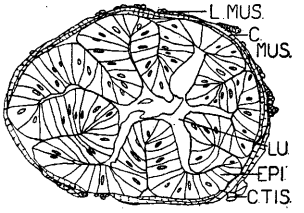

FIG. 13